Draft Chapter 12
RUNOFF REDUCTION METHODOLOGY

12.0 Introduction

The Runoff Reduction Method ("RR Method") was developed for DCR by the Center for Watershed Protection in order to promote better stormwater design and as a tool for compliance with Virginia's proposed regulations. There several shortcomings to existing stormwater design practices that the method seeks to overcome.

The RR Method relies on a three-step compliance procedure, as described below.

Step 1: Apply Site Design Practices to Minimize Impervious Cover, Grading and Loss of Forest Cover

This step focuses on implementing Environmental Site Design (ESD) practices during the early phases of site layout. The goal is to minimize impervious cover and mass grading, and maximize retention of forest cover, natural areas and undisturbed soils (especially those most conducive to landscape-scale infiltration). The RR Method uses a spreadsheet to compute runoff coefficients for forest, disturbed soils, and impervious cover and to calculate a site-specific target treatment volume and phosphorus load reduction target.

Step 2: Apply Runoff Reduction (RR) Practices

In this step, the designer experiments with combinations of nine Runoff Reduction practices on the site. In each case, the designer estimates the area to be treated by each Runoff Reduction practice to incrementally reduce the required treatment volume for the site. The designer is encouraged to use Runoff Reduction practices in series within individual drainage areas (such as rooftop disconnection to a grass swale to a bioretention area) in order to achieve a higher level of runoff reduction.

Step 3: Compute Pollutant Removal (PR) By Selected BMPs

In this step, the designer uses the spreadsheet to see whether the phosphorus load reduction has been achieved by the application of Runoff Reduction practices. If the target phosphorus load limit is not reached, the designer can select additional, conventional BMPs – such as filtering practices, wet ponds, and stormwater wetlands – to meet the remaining load requirement.
In reality, the process is iterative for most sites. When compliance cannot be achieved on the first try, designers can return to prior steps to explore alternative combinations of Environmental Site Design, Runoff Reduction practices, and Pollutant Removal practices to achieve compliance.

A possible Step 4 would involve paying an offset fee (or fee-in-lieu payment) or providing off-site mitigation to compensate for any load that cannot feasibly be met on particular sites. The local government or program authority would need to have a watershed or regional planning structure for stormwater management in order to make this option available for sites within the jurisdiction. The fee would be based on the phosphorus "deficit" – that is, the difference between the target reduction and the actual site reduction after the designer makes his or her best effort to apply Runoff Reduction and Pollutant Removal practices. A related, but simpler option would be to allow a developer to conduct an off-site mitigation project in lieu of full on-site compliance.

A flow chart of the Runoff Reduction Compliance Methodology is on the following page.

12.1 Step-By-Step Instructions for Using the Runoff Reduction Method Spreadsheet

The numbering in these instructions generally follows the process outlined in Document A (flowchart). Tab references refer to the appropriate tab in the spreadsheet. Line references refer to the appropriate line in the spreadsheet.

12.1.1 TAB 1: Site Data

1.A Utilize environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B For the site, indicate post-development impervious, managed turf, and forest/open space land cover in **lines 22-24**. Guidance for various land covers is provided in Table 1.

2. From the land cover input, a weighted site runoff coefficient (Rv) will be calculated (**line 46**), as will the required Post Development Treatment Volume (**lines 48-49**).

3. A Post Development TP Load, and the required TP load reduction, will be calculated based upon the Post Development Treatment Volume (**lines 50-51**).

12.1.2 TAB 2: "D.A. A" (Drainage Area A)

4. If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Indicate the post-development impervious, managed turf, and forest/open space land cover for Drainage Area A in **lines 11-13**.

Runoff Reduction Method Flowchart

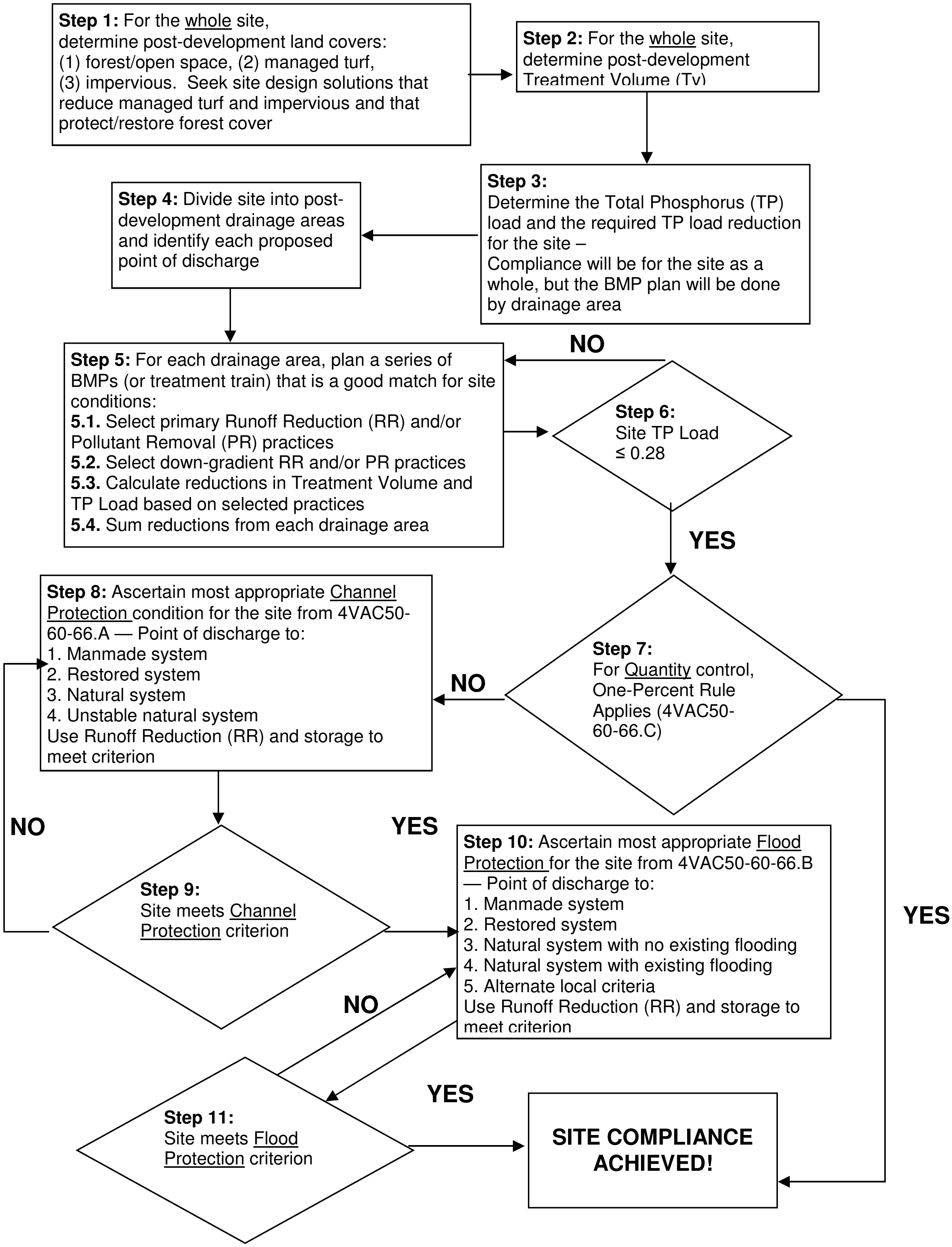

Table 12.1. Land Cover Guidance for Virginia Runoff Reduction Spreadsheet

IMPERVIOUS COVER

- Roadways, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover.
- This category also includes the surface area of stormwater BMPs that: (1) are wet ponds, OR (2) replace an otherwise impervious surface (e.g., green roof, pervious parking).[1]

MANAGED TURF

Land disturbed and/or graded for eventual use as managed turf:

- Portions of residential yards that are graded or disturbed, including yard areas, septic fields, residential utility connections
- Roadway rights-of-way that will be mowed and maintained as turf
- Turf areas intended to be mowed and maintained as turf within residential, commercial, industrial, and institutional settings

FOREST & OPEN SPACE

Land that will remain undisturbed OR that will be restored to a hydrologically functional state:

- Portions of residential yards that will NOT be disturbed during construction
- Portions of roadway rights-of-way that, following construction, will be used as filter strips, grass channels, or stormwater treatment areas; MUST include soil restoration or placement of engineered soil mix as per the design specifications
- Community open space areas that will not be mowed routinely, but left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year)
- Utility rights-of-way that will be left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year)
- Surface area of stormwater BMPs that are NOT wet ponds, have some type of vegetative cover, and that do not replace an otherwise impervious surface. BMPs in this category include bioretention, dry swale, grass channel, extended detention pond that is not mowed routinely, stormwater wetland, soil amended areas that are vegetated, and infiltration practices that have a vegetated cover.
- Other areas of existing forest and/or open space that will be protected during construction and that will remain undisturbed

<u>Operational & Management Conditions for Land Cover in Forest & Open Space Category:</u>

- Undisturbed portions of yards, community open space, and other areas that will be considered as forest/open space must be shown outside the LOD on approved E&S plans AND demarcated in the field (e.g., fencing) prior to commencement of construction.
- Portions of roadway rights-of-way that will count as forest/open space are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration and, if applicable, site reforestation, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP
- All areas that will be considered forest/open space for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state. Appropriate documentation includes: subdivision covenants and restrictions, deeded operation and maintenance agreements and plans, parcel of common ownership with maintenance plan, third-party protective easement, within public right-of-way or easement with maintenance plan, or other documentation approved by the local program authority
- While the goal is to have forest/open space areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the local program authority: forest management, control of invasive species, replanting and revegetation, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc.

[1] Certain stormwater BMPs are considered impervious with regard to the land cover computations. These BMPs are still assigned Runoff Reduction and/or Pollutant Removal rates within the spreadsheet, so their "values" for stormwater management are still accounted for. The reason they are considered impervious is that they either do not reduce runoff volumes (e.g., wet ponds) OR their Runoff Reduction rates are based on comparison to a more conventional land cover type (e.g., green roofs, pervious parking).

5.1.A. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating in **column G** the number of acres to be treated by a given RR practice. Note that some RR practices are divided into turf area and impervious area to be treated. The site designer should select the most strategic locations on the site to place RR practices (e.g., drainage areas with the most developed land). This will likely be an iterative process. The available RR Practices include:

- Green roof
- Impervious surface disconnection
- Permeable pavement
- Grass channel
- Dry swale
- Bioretention
- Wet swale
- Infiltration
- Extended detention pond
- Sheetflow to conservation area or filter strip

5.1.B. Based upon the runoff reduction capability of the selected BMP, the spreadsheet will calculate the Runoff Reduction Volume in **column I** and the Remaining Runoff Volume in **column J.**

5.1.C. These practices also have a pollutant removal efficiency (**column K**), which will be applied to the remaining runoff volume (after runoff reduction has been applied). The spreadsheet will calculate the pollutant removal in **column N**.

5.2.A. If a secondary RR practice or a pollutant removal practice will be utilized in sequence downstream of the primary RR practice (for example, 2 acres of impervious rooftop are to be treated first with a green roof, and then, after discharge from the roof, will be conveyed via a dry swale), select the downstream RR practice from the pull-down menu in **column P** (click on the blue box in column K to see the pull-down menu). The spreadsheet will calculate the Remaining Runoff Volume and then direct it to the selected downstream RR practice via **column H**, and the remaining phosphorus load to **column L.** Sequences of three or more practices can be accommodated as well.

5.2.B. Select all the RR practices that will be used for the drainage area. Note that it is possible for a RR practice to be a downstream practice for one area, and a primary practice for another (Using the example above, a dry swale can receive discharge from a green roof and can also receive runoff directly from an impervious parking area.). It is also possible for more than one primary practice to be directed to the same downstream practice. However, the spreadsheet will not allow runoff from one primary practice to be diverted into two different downstream practices. If a site design calls for this, the site will need to be divided into separate drainage areas, or the design worksheet may be utilized instead of the spreadsheet.

5.3.A. From the selected RR practices, the total runoff reduction will be calculated on **line 77**, along with the TP load reduction achieved, the adjusted TP load, and the remaining TP load reduction needed on **lines 78, 79, and 80** respectively**.**

5.3.B. The phosphorous load calculations on lines 77 through and 79 account for both the runoff reduction and pollutant removal achieved by runoff reduction practices. Additional practices, such as filters, ponds and wetlands remove phosphorous from runoff via settling, filtering, biological uptake, and other processes, but do not achieve runoff reductions. These practices should be viewed as supplemental to runoff reduction measures. **Lines 86-107** account for pollutant removal from practices that do not provide runoff reduction. Indicate acres of turf or impervious cover that drain to these practices *without* first being treated by another practice in **Column D.** The remaining phosphorus load and (unchanged) runoff volume can then be directed to a downstream practice chosen in **Column J.** Runoff volume and phosphorus load from upstream practices are included **Columns F and G**, respectively, for these practices.

5.3.C. The TP load reduction for the practices on lines 86-107 are calculated in **Column I** and summed on **cell I109**. This load is added to the phosphorus removal achieved by upstream runoff reduction practices and totaled in **cell I110.** The remaining TP load reduction needed for the site is indicated in **cell I112**.

13.1.3 TAB 3: D.A. B (Drainage Area B)

Lines 5-6 indicate the status of the TP load requirements from sheet "D.A. A," summarizing the required additional TP load reduction is necessary for compliance.

If there is only one drainage area for the site, sheet "D.A. B" should be left blank. If there is more than one Drainage area, fill out "D.A. B" in the same manner as "D.A. A."

13.1.4 TAB 4: Water Quality Compliance

6. The water quality compliance sheet summarizes the runoff reduction and pollutant removal results for the site. **Line 11** will indicate if additional TP load needs to be removed. If there is still a TP load to remove after applying runoff reduction and pollutant removal practices on "D.A. A" and "D.A. B," the site should be reconfigured to reduce impervious or turf areas, or additional RR practices and pollutant removal practices must be selected on sheets "D.A. A" and "D.A.B."

13.1.5 TAB 5: Channel and Flood Protection

This sheet assists with calculation of the channel protection and flood control volumes necessary for the site.

7. Compare the site area to the total watershed area draining to the point of discharge, and the post-development peak flow from the site for the 1-year storm (see steps 8.A-D below) to the 1-year storm peak flow for the total watershed area draining to the point of discharge. If the site area is less than one percent of the watershed area, or the 1-year

post-development peak flow is less than one percent of the watershed peak flow at the point of discharge, channel protection and flood protection requirements do not apply.

8.A Indicate the appropriate regional depths for the 1-year, 2-year, and 10-year 24-hour storms on **Line 2**.

8.B Each land cover and soil type is associated with a Natural Resource Conservation Service (NRCS) curve number. Using these curve numbers, a weighted curve number and the total runoff volume for each drainage area are calculated. **Lines 24 and 38** calculate the runoff volume without regard to the RR practices employed on the site. **Lines 25 and 39** Then subtract the volume treated by the RR practices from these totals.

The spreadsheet then determines the curve number that results in the calculated runoff volume with RR practices. This adjusted curve number is reported on **lines 26 and 40.**

8.C. Indicate the time of concentration for each drainage area on **lines 46 and 57**. This value will be dependent upon land cover types, slopes, and flow path lengths. It may also be extended due to the use of certain RR practices. The Curve Number (calculated in 8.B. above) is used to determine the value of "S" (storage in the watershed) and the "Initial Abstraction." These values are determined using equations from the USDA, NRCS document, "*Urban Hydrology for Small Watersheds*" also known as TR-55. Regression equations also included in this document were used to determine the "unit peak discharge" based on the values of the Time of concentration and the "Ia/P" (or initial abstraction divided by precipitation) value. This unit peak discharge rate (in cfs/square mile/inch of runoff) is then converted to a peak discharge rate in cfs.

8.D. If condition 4 for either the channel protection or flood control regulations is to be used, data for the forested condition are required. **Lines 65-102** can be ignored otherwise. The forested runoff volume is automatically calculated on **Lines 74 and 85** using data from each drainage area. **On lines 90 and 100**, indicate the time of concentration for each drainage area. The resulting forested peak discharge rates are then calculated on **lines 92 and 102**.

Channel Protection Conditions

9.A To meet condition 1, demonstrate that the developed peak runoff from the 2-year 24-hour storm is conveyed without causing erosion of the system.

9.B To meet condition 2, demonstrate that the runoff from the developed site, in combination with other existing stormwater runoff, will not exceed the design of the restored stormwater conveyance system nor result in instability of the system.

9.C To meet condition 3, indicate the pre-developed land cover types for each drainage area on **lines 120-128.** The pre-developed runoff volume for the 1-year storm will then be calculated on **lines 142 and 154**. Indicate the time of concentration for each drainage area for the pre-developed site on **line 159**. The peak discharge will then be calculated and reported on **line 161.**

To meet condition 3, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow:
Allowable $Q_{Developed} = Q_{Pre\text{-}Developed} \times V_{Pre\text{-}Developed} / V_{Developed}$

Where:
Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 3 (cubic feet per second)
$Q_{Pre\text{-}Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)
$V_{Pre\text{-}Developed}$ = Runoff volume for the pre-developed condition (inches)
$V_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Line 170 calculates the allowable $Q_{Developed}$. **Line 171** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 171 to the allowable peak runoff on line 170. Note that if, on tabs "D.A. A" or "D.A. B," Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

9.D To meet condition 4, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow:
Allowable $Q_{Developed} = Q_{Forested} \times V_{Forested} / V_{Developed}$

Where:
Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 4 (cubic feet per second)
$Q_{forested}$ = peak runoff rate for the drainage area in the forested condition (cubic feet per second)
$V_{forested}$ = Runoff volume for the forested condition (inches)
$V_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Line 179 calculates the allowable $Q_{Developed}$. **Line 180** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 180 to the allowable peak runoff on line 179. Note that if, on sheets "D.A. A" or "D.A. B," Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement.

Flood Control Conditions

10. Using the calculations under 8A. through 8.B. above, determine the peak discharge rates for the relevant water flood control storms.

11.A. To meet conditions 1, 2, or 3, demonstrate that the developed peak runoff from the 10-year 24-hour storm is confined within the man-made conveyance system.

11.B. To meet condition 4, the maximum allowable peak runoff from the 10-year 24-hour storm is equal to the peak runoff from the site in a forested condition. **Line 200** indicates the allowable $Q_{Developed}$ based upon this requirement. **Line 201** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 201 to the allowable peak runoff on line 200. Note that if, on tabs “D.A. A” or “D.A. B”, Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

11.C Since condition 5 is dependent upon local determination, it is not included in the spreadsheet.

12.2 Supplemental Instructions for Using the Redevelopment Version of the Runoff Reduction Method Spreadsheet

For redevelopment sites, use these instructions for Tab 1: Site Data. Use the instructions in this section for the remainder of the spreadsheet.

TAB 1: Site Data

1.A Utilize environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B For the site, indicate pre-development impervious, managed turf, and forest/open space land cover in **lines 22-24**. Then do the same for post-development in **lines 29-31**. Guidance for various land covers is provided in **Table 12.1** above.

2. From the land cover input, a weighted site runoff coefficients (Rv) will be calculated (line 54), as will the Pre- and Post-Development Treatment Volume (lines 56-57).

3. A Pre- and Post-Development TP Load will be calculated (**line 58**). Using these values, the required TP Load Reduction will be calculated (**line 60**) based upon the reduction requirement to decrease TP loads by 20%, or meet the target TP load of .28 pounds / acre / year, whichever is less stringent.

12.3 DOCUMENT C: DOCUMENTATION FOR THE RUNOFF REDUCTION METHOD

This section contains basic methods and computations that are built into the spreadsheet procedures. It combines the process with the equations. It is intended for users who want to verify or adapt the method.

12.3.1 Site Data Sheet

1.A Utilize environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B For the site, indicate post-development impervious, managed turf, and forest/open space land cover in **lines 22-24**. Guidance for various land covers is provided in **Table 12.1** above.

2. From the land cover input, a weighted site runoff coefficient (Rv) will be calculated (line 46), as will the required Post Development Treatment Volume (lines 48-49).

Land Cover Rv:

Rv(F) = [(A(fA) x 0.02) + (A(fB) x 0.03) + (A(fC) x 0.04) + (A(fD) x 0.05)]/SA
Rv(T) = [(A(tA) x 0.15) + (A(tB) x 0.20) + (A(tC) x 0.22) + (A(tD) x 0.25)]/SA
Rv(I) = 0.95
%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA x 100
%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA x 100
%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA x 100

Where:

Rv(F) = weighted forest runoff coefficient
A(fA) = area of post-development preserved or restored forest in A soils (acres)
A(fB) = area of post-development preserved or restored forest in B soils (acres)
A(fC) = area of post-development preserved or restored forest in C soils (acres)
A(fD) = area of post-development preserved or restored forest in D soils (acres)

Rv(T) = weighted turf runoff coefficient
A(tA) = area of post-development managed turf in A soils (acres)
A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

Rv(I) = weighted impervious cover runoff coefficient

A(iA) = area of post-development impervious cover in A soils (acres)
A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

SA = total site area (acres)

Site Rv:
Rv(S) = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

Where:
Rv(S) = runoff coefficient for the site
Rv(F) = weighted forest runoff coefficient
Rv(T) = weighted turf runoff coefficient
Rv(I) = weighted impervious cover runoff coefficient

Post Development Treatment Volume:
Tv(S) = Rd x Rv(S) x SA/12

Where:
Tv(S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1" for water quality storm)
Rv(S) = runoff coefficient for the site
SA = total site area (acres)

3. A Post Development TP Load, and the required TP load reduction will be calculated based upon the Post Development Treatment Volume (lines 50-51).

Post Development TP Load:
$L = P \times P_j \times [Tv(S)/Rd] \times C \times 2.72$

Where:
L = post-development pollutant load for site (pounds / year of total phosphorus)
P = average annual rainfall depth (inches) = 43 inches for Virginia
P_j = fraction of rainfall events that produce runoff = 0.9
Tv(S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1" for water quality storm)
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Required TP Load Reduction:
Lreduction = L – Ptarget x SA

Where:
Lreduction = required TP Load Reduction (pounds / year of total phosphorous

L = post-development pollutant load for site (pounds / year of total phosphorus)
Ptarget = Target phosphorous load (pounds / acre / year)
SA = total site area (acres)

12.3.2 D.A. A

4. If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Indicate the post-development impervious, managed turf, and forest/open space land cover for Drainage Area A in **lines 11-13**.

5.1.A. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating in **column G** the number of acres to be treated by a given RR practice. Note that some RR practices are divided into turf area and impervious area to be treated. The site designer should select the most strategic locations on the site to place RR practices (e.g., drainage areas with the most developed land). This will likely be an iterative process. The available RR Practices include:

- Green roof
- Impervious surface disconnection
- Permeable pavement
- Grass channel
- Dry swale
- Bioretention
- Wet swale
- Infiltration
- Extended detention pond
- Sheetflow to conservation area or filter strip

5.1.B. Based upon the runoff reduction capability of the selected BMP, the spreadsheet will calculate the Runoff Reduction Volume in **column I** and the Remaining Runoff Volume in **column J.**

Adjustment to Treatment Volume:

$$Cv(x) = (Rd \times Rv(\text{land cover}) \times CA \times 3630 + V_{upstream}) \times CR$$

Where:

Cv(x) = Adjustment to treatment volume based on application of credit X (cubic feet)
Rd = rainfall depth for target event (1” for water quality storm)
Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
CA = area credit applied to (acres)
3630 = unit adjustment factor, converting acre-inches to cubic feet
$V_{upstream}$ = Upstream runoff volume directed to credit practice
CR = credit (fraction of runoff eliminated by the credit practice)

5.1.C. These practices also have a pollutant removal efficiency (**column K**), which will be applied to the remaining runoff volume (after runoff reduction has been applied). The spreadsheet will calculate the adjustment to the phosphorus load in **column N**:

Pollutant Load to the Practice:

$L(x) = L_{upstream} + [Rv(\text{land cover}) \times CA \times P \times Pi/12 - CV(x)/43{,}560] \times 2.72 \times EMC$

Where:

- $L(x)$ = Pollutant Load to the Practice (pounds/yr)
- $L_{upstream}$ = Pollutant load from upstream treatment practices
- Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
- CA = area credit applied to (acres)
- P = average annual rainfall depth (inches) = 43 inches for Virginia
- Pj = fraction of rainfall events that produce runoff = 0.9
- 12 = unit adjustment factor, converting acre-inches to acre-ft
- 43,560 = unit adjustment factor, cubic feet to acre-ft
- Cv(x) = adjustment to treatment volume based on application of BMP credit ($ft.^3$)
- EMC = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
- 2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Pollutant Removal (or Load Reduction):

$LR(x) = L(x) * [Cv(x) + ATv(x) * EFF_{TP} / 100] / [Cv(x) + ATv(x)]$

Where:

- LR(x) = Load Reduction (lbs/year)
- L(x) = Load to the practice (lbs/year)
- Cv(x) = Cv(x) = adjustment to treatment volume based on application of BMP credit (cubic ft)
- ATv(x) = Remaining Runoff Volume after credit X is applied (cubic feet) (See 5.2A below)
- EFF_{TP} = Total Phosphorus pollutant removal efficiency
- 100 = % conversion factor

5.2.A. If a secondary RR practice or a pollutant removal practice will be utilized in sequence downstream of the primary RR practice (for example, 2 acres of impervious rooftop are to be treated first with a green roof, and then, after discharge from the roof, will be conveyed via a dry swale), select the downstream RR practice from the pull-down menu in **column P** (click on the blue box in column K to see the pull-down menu). The spreadsheet will calculate the Remaining Runoff Volume and then direct it to the selected downstream RR practice via **column H**, and the remaining phosphorus load to **column L.** Sequences of three or more practices can be accommodated as well.

Remaining Runoff Volume:
ATv(x) = (Rd x Rv(land cover) x CA x 3630 + Vupstream) x (1-CR)

Where:
ATv(x) = Remaining Runoff Volume after credit X is applied (cubic feet)
Rd = rainfall depth for target event (1" for water quality storm)
Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
CA = area credit applied to (acres)
3630 = unit adjustment factor, converting acre-inches to cubic feet
$V_{upstream}$ = Upstream runoff volume directed to credit practice
CR = credit (fraction of runoff eliminated by the credit practice)

Remaining Phosphorus Load:
AL(x) = L(x) - LR(x)

Where:
AL(x) = Remaining Phosphorus Load after treatment by the practice (lb/year)
L(x) = Load to the practice (lbs/year)
LR(x) = Load Reduction (lbs/year)

5.2.B. Select all the RR practices that will be used for the drainage area. Note that it is possible for a RR practice to be a downstream practice for one area, and a primary practice for another (Using the example above, a dry swale can receive discharge from a green roof and can also receive runoff directly from an impervious parking area.). It is also possible for more than one primary practice to be directed to the same downstream practice. However, the spreadsheet will not allow runoff from one primary practice to be diverted into two different downstream practices. If a site design calls for this, the site will need to be divided into separate drainage areas, or the design worksheet may be utilized instead of the spreadsheet.

5.3.A. From the selected RR practices, the total runoff reduction will be calculated on **line 77**, along with the TP load reduction achieved, the adjusted TP load, and the remaining TP load reduction needed on **lines 78, 79, and 80** respectively**.**

Total Adjustment to Treatment Volume:
Cv = ∑Cv(x)

Where:
Cv = total adjustment to treatment volume for the drainage area through application of credits (cubic ft)
Cv(x) = Adjustment to treatment volume based on application of credit X (cubic feet)

Adjusted Treatment Volume:
ATv = Tv - Cv/43560

Where:
- ATv = adjusted treatment volume for site after application of credits (acre-ft)
- Tv = post-development treatment volume for site (acre-ft)
- Cv = total adjustment to treatment volume through application of credits ($ft.^3$)

Total Load Reduction Achieved:
$LR_{RR} = \sum LR(x)$
LR_{RR} = Load Reduction achieved by Runoff Reduction Measures
LR(x) = Pollutant Removal Achieved by individual runoff reduction practice (pounds)

Adjusted Phosphorous Load:
$AL_{RR} = L - LR_{RR}$

Where:
- AL_{RR} = Adjusted Load after the application of credits through runoff reduction practices.
- L = post-development pollutant load for site (pounds / year of total phosphorus)
- LR_{RR} = Load Reduction achieved by Runoff Reduction Measures

Remaining Load Reduction Required:
$RR = AL_{RR} – (P_{target} \times SA)$

Where:
- RR = remaining load required to be removed after application of credits (pounds/ year of total phosphorus)
- AL_{RR} = adjusted post-development pollutant load for site after application of credits (pounds/ year of total phosphorus)
- P_{target} = Target phosphorous load (pounds / acre / year)
- SA = total site area (acres)

5.3.B. The phosphorous load calculations on lines 77 through and 79 account for both the runoff reduction and pollutant removal achieved by runoff reduction practices. Additional practices, such as filters, ponds and wetlands remove phosphorous from runoff via settling, filtering, biological uptake, and other processes, but do not achieve runoff reductions. These practices should be viewed as supplemental to runoff reduction measures. **Lines 86-107** account for pollutant removal from practices that do not provide runoff reduction. Indicate acres of turf or impervious cover that drain to these practices *without* first being treated by another practice in **Column D.** The remaining phosphorus load and (unchanged) runoff volume can then be directed to a downstream practice chosen in **Column J.** Runoff volume and phosphorus load from upstream practices are included **Columns F and G**, respectively, for these practices.

5.3.C. The TP load reduction for the practices on lines 86-107 are calculated in **Column I** and summed on **cell I109**. This load is added to the phosphorus removal achieved by upstream runoff reduction practices and totaled in **cell I110.** The remaining TP load reduction needed for the site is indicated on **cell I112**.

Phosphorous Load Reduction:

$LR(x) = [L_{upstream} + P \text{ x } Pi \text{ x } Rv(\text{land cover}) \text{ x } A/12 \text{ x } EMC \text{ x } 2.72] \text{x } EFF_{TP} / 100$

Where:

LR(x) = Pollutant Removal Achieved by individual BMP (pounds)
Lupstream = Phosphorus Load from upstream practices
P = average annual rainfall depth (inches) = 43 inches for Virginia
Rv(land cover) = weighted runoff coefficient for land cover being treated by the BMP
A = Area draining to the practice (acres)
EMC = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
12 = unit adjustment factor, converting acre-inches to acre-ft
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters
EFF_{TP} = Total Phosphorus pollutant removal efficiency
100 = % conversion factor

Total Phosphorous Load Reduction:

$LR = \sum LR(x)+LR_{RR}$

Where:

LR = Total Pollutant Removal Achieved (pounds / year of total phosphorous)
LR(x) = Pollutant Removal Achieved by individual BMP (pounds / year of total phosphorous)
LR_{RR} = Load Reduction achieved by Runoff Reduction Measures (lbs/year)

Remaining Pollutant Removal Required:

$LR_{remaining} = RR - LR$

Where:

$LR^{remaining}$ = Remaining Pollutant Removal required (pounds / year of total phosphorous)
RR = remaining load required to be removed after application of runoff reduction credits (pounds/ year of total phosphorus)
LR = Total Pollutant Removal Achieved (pounds / year of total phosphorous)

12.3.3 D.A. B

Lines 5-6 indicate the status of the TP load requirements from sheet “D.A. A,” summarizing the required additional TP load reduction is necessary for compliance.

If there is only one drainage area for the site, sheet "D.A. B" should be left blank. If there is more than one Drainage area, fill out "D.A. B" in the same manner as "D.A. A."

Water Quality Compliance:

6. The water quality compliance sheet summarizes the runoff reduction and pollutant removal results for the site. **Line 11** will indicate if additional TP load needs to be removed. If there is still a TP load to remove after applying runoff reduction and pollutant removal practices on "D.A. A" and "D.A. B," the site should be reconfigured to reduce impervious or turf areas, or additional RR practices and pollutant removal practices must be selected on sheets "D.A. A" and "D.A.B."

Channel and Flood Protection:

This sheet assists with calculation of the channel protection and flood control volumes necessary for the site.

7. Compare the site area to the total watershed area draining to the point of discharge, and the post-development peak flow from the site for the 1-year storm (see steps 8.A-D below) to the 1-year storm peak flow for the total watershed area draining to the point of discharge. If the site area is less than one percent of the watershed area, or the 1-year post-development peak flow is less than one percent of the watershed peak flow at the point of discharge, channel protection and flood protection requirements do not apply.

8.A Indicate the appropriate regional depths for the 1-year, 2-year, and 10-year 24-hour storms on **Line 2**.

8.B Each land cover and soil type is associated with a Natural Resource Conservation Service (NRCS) curve number. Using these curve numbers, a weighted curve number and the total runoff volume for each drainage area are calculated. **Lines 24 and 38** calculate the runoff volume without regard to the RR practices employed on the site. **Lines 25 and 39** Then subtract the volume treated by the RR practices from these totals.

Weighted Curve Number:

CN = [(A(fA) x 30) + (A(fB) x 55) + (A(fC) x 70) + (A(fD) x 77)+ (A(tA) x 39) + (A(tB) x 61) + (A(tC) x 74) + (A(tD) x 80) + A(iA) x 98) + (A(iB) x 98) + (A(iC) x 98) + (A(iD) x 98)]/DA

Where:

CN = weighted curve number
A(fA) = area of post-development preserved or restored forest in A soils (acres)
A(fB) = area of post-development preserved or restored forest in B soils (acres)
A(fC) = area of post-development preserved or restored forest in C soils (acres)
A(fD) = area of post-development preserved or restored forest in D soils (acres)

A(tA) = area of post-development managed turf in A soils (acres)

A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

A(iA) = area of post-development impervious cover in A soils (acres)
A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

DA = Drainage Area (acres)

Potential Abstraction:
$S = 1000/(CN-10)$

Where:
S = Potential Abstraction (inches)
CN = weighted curve number

Runoff Volume with no Runoff Reduction:
$V = (P - 0.2 \times S)^2 /(P + 0.8 \times S)$

Where:
V = Runoff volume with no runoff reduction (inches)
P = Precipitation depth for a given 24-hour storm (inches)
S = Potential Abstraction (inches)

Runoff Volume with Runoff Reduction:
$V_{rr} = V - (Cv(da) / 3630 / DA$

Where:
Vrr = Runoff volume with runoff reduction (inches)
Cv(da) = total adjustment to treatment volume for the drainage area through application of runoff reduction credits (cubic ft)
3630 = unit adjustment factor, cubic feet to acre-inches
DA = drainage area (acres)

The spreadsheet then determines the curve number that results in the calculated runoff volume with RR practices. This adjusted curve number is reported on **lines 26 and 40.**

Adjusted Curve Number:
The adjusted curve number is calculated using a lookup table of curve number and runoff volumes so that:

$CN_{adjusted}$, so $(P-0.2 \times S_{adjusted})^2 / (P + 0.8 \times S_{adjusted}) = V_{rr}$

$S_{adjusted} = 1000/(CN_{adjusted} - 10)$

Where:

$CN_{adjusted}$ = Adjusted curve number that will create a runoff volume equal to the drainage area runoff volume including runoff reduction practices
P = Precipitation depth for a given 24-hour storm (inches)
Sadjusted = Adjusted potential abstraction based upon adjusted curve number (inches)
Vrr = Runoff volume with runoff reduction (inches)

8.C. Indicate the time of concentration for each drainage area on **lines 46 and 57**. This value will be dependent upon land cover types, slopes, and flow path lengths. It may also be extended due to the use of certain RR practices. The Curve Number (calculated in 8.B. above) is used to determine the value of "S" (storage in the watershed) and the "Initial Abstraction." These values are determined using equations from the USDA, NRCS document, "*Urban Hydrology for Small Watersheds*" also known as TR-55. Regression equations also included in this document were used to determine the "unit peak discharge" based on the values of the Time of concentration and the "Ia/P" (or initial abstraction divided by precipitation) value. This unit peak discharge rate (in cfs/square mile/inch of runoff) is then converted to a peak discharge rate in cfs.

Ia / P Ratio:

$Ia / P = 0.2 \times S_{adjusted} / P$

Where:

Ia = Initial Abstraction (inches)
P = Precipitation depth for a given 24-hour storm (inches)
$S_{adjusted}$ = Adjusted potential abstraction based upon adjusted curve number (inches)

Unit Peak Discharge (qu):

The unit peak discharge (in cfs/sm/inch of runoff)

$$\log(q_u) = C_0 + C_1 * \log(T_C) + C_2 * [\log(T_C)]^2$$

Where:

qu = unit peak discharge (cfs/sm/inch of runoff)
Ci = dimensionless constants
Tc = time of concentration (hrs)

Determining Constants:

The constants are interpolated between the following values:

Table 12.2.

Ia / P :	**0.10**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**
C0 :	2.55323	2.46532	2.41896	2.36409	2.29238	2.20282
C1 :	0.61512	0.62257	0.61594	0.59857	0.57005	0.51599
C2 :	0.16403	0.11657	0.08820	0.05621	0.02281	0.01259

Peak Runoff:
Q_{peak} = qu x DA / 640 x V_{rr}

Where:
- Q_{peak} = peak runoff rate for the drainage area (cubic feet per second)
- qu = unit peak discharge (cubic feet per second per square mile per inch)
- DA = drainage area (acres)
- 640 = unit adjustment factor, converting acres to square miles
- Vrr = Runoff volume with runoff reduction (inches)

8.D. If condition 4 for either the channel protection or flood control regulations is to be used, data for the forested condition are required. **Lines 65-102** can be ignored otherwise. The forested runoff volume is automatically calculated on **Lines 74 and 85** using data from each drainage area. **On lines 90 and 100**, indicate the time of concentration for each drainage area. The resulting forested peak discharge rates are then calculated on **lines 92 and 102**.

Weighted Curve Number:
$CN_{forested}$ = [(A(A) x 30) + (A(B) x 55) + (A(C) x 70) + (A(D) x 77)]/DA

Where:
- CNforested = weighted curve number for the forested condition
- A(A) = area of land in A soils (acres)
- A(B) = area of land in B soils (acres)
- A(C) = area of land in C soils (acres)
- A(D) = area of land in D soils (acres)
- DA = drainage area (acres)

Channel Protection Conditions

9.A To meet condition 1, demonstrate that the developed peak runoff from the 2-year 24-hour storm is conveyed without causing erosion of the system.

9.B To meet condition 2, demonstrate that the runoff from the developed site, in combination with other existing stormwater runoff, will not exceed the design of the restored stormwater conveyance system nor result in instability of the system.

9.C To meet condition 3, indicate the pre-developed land cover types for each drainage area on **lines 120-128.** The pre-developed runoff volume for the 1-year storm will then be calculated on **lines 142 and 154**. Indicate the time of concentration for each drainage area for the pre-developed site on **line 159**. The peak discharge will then be calculated and reported on **line 161.**

To meet condition 3, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow:
Allowable $Q_{Developed} = Q_{Pre\text{-}Developed} \times V_{Pre\text{-}Developed} / V_{Developed}$

Where:
Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 3 (cubic feet per second)
$Q_{Pre\text{-}Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)
$V_{Pre\text{-}Developed}$ = Runoff volume for the pre-developed condition (inches)
$V_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Weighted Curve Number:
$CN_{Pre\text{-}Developed} = [(A_{Pre\text{-}Developed}(fA) \times 30) + (A_{Pre\text{-}Developed}(fB) \times 55) + (A_{Pre\text{-}Developed}(fC) \times 70) + (A_{Pre\text{-}Developed}(fD) \times 77) + (A_{Pre\text{-}Developed}(tA) \times 39) + (A_{Pre\text{-}Developed}(tB) \times 61) + (A_{Pre\text{-}Developed}(tC) \times 74) + (A_{Pre\text{-}Developed}(tD) \times 80) + (A_{Pre\text{-}Developed}(iA) \times 98) + (A_{Pre\text{-}Developed}(iB) \times 98) + (A_{Pre\text{-}Developed}(iC) \times 98) + (A_{Pre\text{-}Developed}(iD) \times 98)]/DA$

Where:
$CN_{Pre\text{-}Developed}$ = weighted curve number for pre-developed condition
$A_{Pre\text{-}Developed}(fA)$ = area of pre-develop. preserved or restored forest in A soils (acres)
$A_{Pre\text{-}Developed}(fB)$ = area of pre-develop. preserved or restored forest in B soils (acres)
$A_{Pre\text{-}Developed}(fC)$ = area of pre-develop. preserved or restored forest in C soils (acres)
$A_{Pre\text{-}Developed}(fD)$ = area of pre-develop. preserved or restored forest in D soils (acres)

$A_{Pre\text{-}Developed}(tA)$ = area of pre-development managed turf in A soils (acres)
$A_{Pre\text{-}Developed}(tB)$ = area of pre-development managed turf in B soils (acres)
$A_{Pre\text{-}Developed}(tC)$ = area of pre-development managed turf in C soils (acres)
$A_{Pre\text{-}Developed}(tD)$ = area of pre-development managed turf in D soils (acres)

$A_{Pre\text{-}Developed}(iA)$ = area of pre-development impervious cover in A soils (acres)
$A_{Pre\text{-}Developed}(iB)$ = area of pre-development impervious cover in B soils (acres)
$A_{Pre\text{-}Developed}(iC)$ = area of pre-development impervious cover in C soils (acres)
$A_{Pre\text{-}Developed}(iD)$ = area of pre-development impervious cover in D soils (acres)

DA = Drainage Area (acres

Potential Abstraction:

$S_{Pre-Developed} = 1000/(CN_{Pre-Developed} - 10)$

Where:

$S_{Pre-Developed}$ = Potential Abstraction for pre-developed condition (inches)
$CN_{Pre-Developed}$ = weighted curve number for pre-developed condition

Pre-Developed Runoff Volume:

$V_{Pre-Developed} = (P - 0.2 \times S_{Pre-Developed})^2 / (P + 0.8 \times S_{Pre-Developed})$

Where:

$V_{Pre-Developed}$ = Runoff volume for the pre-developed condition (inches)
P = Precipitation depth for a given 24-hour storm (inches)
$S_{Pre-Developed}$ = Potential Abstraction for pre-developed condition (inches)

Ia / P Ratio:

$Ia_{Pre-Developed} / P = 0.2 \times S_{Pre-Developed} / P$

Where:

$Ia_{Pre-Developed}$ = Initial Abstraction for the pre-developed condition (inches)
P = Precipitation depth for a given 24-hour storm (inches)
$S_{Pre-Developed}$ = Potential Abstraction for pre-developed condition (inches)

Peak Runoff:

$Q_{Pre-Developed} = qu_{Pre-Developed} \times DA / 640 \times V_{Pre-Developed}$

Where:

$Q_{Pre-Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)
$qu_{Pre-Developed}$ = unit peak discharge for the pre-developed condition (cubic feet per second per square mile per inch)
DA = drainage area (acres)
640 = unit adjustment factor, converting acres to square miles
$V_{Pre-Developed}$ = Runoff volume for the pre-developed condition (inches)

To meet condition 3, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow:

Allowable $Q_{Developed} = Q_{Pre-Developed} \times V_{Pre-Developed} / V_{Developed}$

Where:

Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 3 (cubic feet per second)
$Q_{Pre-Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)

$V_{Pre\text{-}Developed}$ = Runoff volume for the pre-developed condition (inches)
$V_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Line 170 calculates the allowable $Q_{Developed}$. **Line 171** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 171 to the allowable peak runoff on line 170. Note that if, on sheets "D.A. A" or "D.A. B," Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

9.D To meet condition 4, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow:
Allowable $Q_{Developed} = Q_{Forested} \times V_{Forested} / V_{Developed}$

Where:
Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 4 (cubic feet per second)
$Q_{forested}$ = peak runoff rate for the drainage area in the forested condition (cubic feet per second)
$V_{forested}$ = Runoff volume for the forested condition (inches)
$V_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Line 179 calculates the allowable $Q_{Developed}$. **Line 180** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 180 to the allowable peak runoff on line 179. Note that if, on sheets "D.A. A" or "D.A. B," Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement.

Flood Control Conditions

10. Using the calculations under 8A. through 8.B. above, determine the peak discharge rates for the relevant water flood control storms.

11.A. To meet conditions 1, 2, or 3, demonstrate that the developed peak runoff from the 10-year 24-hour storm is confined within the man-made conveyance system.

11.B. To meet condition 4, the maximum allowable peak runoff from the 10-year 24-hour storm is equal to the peak runoff from the site in a forested condition. **Line 200** indicates the allowable $Q_{Developed}$ based upon this requirement. **Line 201** indicates the peak runoff from the post-development site with no detention. Detention or other means must be provided to reduce the developed peak runoff on line 201 to the allowable peak runoff on line 200. Note that if, on sheets "D.A. A" or "D.A. B," Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet this requirement. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

11.C Since condition 5 is dependent upon local determination, it is not included in the spreadsheet.

12.4 Supplemental Documentation for the Redevelopment Version of the Runoff Reduction Method

This supplemental documentation applies to Tab 1: Site Data for redevelopment sites. This section provides the computation documentation for the remainder of the spreadsheet.

TAB 1: Site Data

1.A Utilize environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B For the site, indicate pre-development impervious, managed turf, and forest/open space land cover in **lines 22-24**. Then do the same for post-development in **lines 29-31**. Guidance for various land covers is provided in **Table 12.1** above.

2. From the land cover input, weighted site runoff coefficients (Rv) will be calculated, as will the Pre- and Post-Development Treatment Volume.

Land Cover Rv:
Rv(F) = [(A(fA) x 0.02) + (A(fB) x 0.03) + (A(fC) x 0.04) + (A(fD) x 0.05)]/SA
Rv(T) = [(A(tA) x 0.15) + (A(tB) x 0.20) + (A(tC) x 0.22) + (A(tD) x 0.25)]/SA
Rv(I) = 0.95
%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA x 100
%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA x 100
%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA x 100

Where:
Rv(F) = weighted forest runoff coefficient
A(fA) = area of pre- or post-development preserved or restored forest in A soils (acres)
A(fB) = area of pre- or post-development preserved or restored forest in B soils (acres)

A(fC) = area of pre- or post-development preserved or restored forest in C soils (acres)
A(fD) = area of pre- or post-development preserved or restored forest in D soils (acres)

Rv(T) = weighted turf runoff coefficient
A(tA) = area of pre- or post-development managed turf in A soils (acres)
A(tB) = area of pre- or post-development managed turf in B soils (acres)
A(tC) = area of pre- or post-development managed turf in C soils (acres)
A(tD) = area of pre- or post-development managed turf in D soils (acres)

Rv(I) = impervious runoff coefficient
A(iA) = area of pre- or post-development impervious cover in A soils (acres)
A(iB) = area of pre- or post-development impervious cover in B soils (acres)
A(iC) = area of pre- or post-development impervious cover in C soils (acres)
A(iD) = area of pre- or post-development impervious cover in D soils (acres)

SA = total site area (acres)

Site Rv:
Rv(S) = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

Where:
Rv(S) = runoff coefficient for the site
Rv(F) = weighted forest runoff coefficient
Rv(T) = weighted turf runoff coefficient
Rv(I) = weighted impervious cover runoff coefficient

Treatment Volume:
Tv(S) = Rd x Rv(Site) x SA/12

Where:
Tv(S) = pre- or post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1” for water quality storm)

3. A Pre- and Post-Development TP Load will be calculated. Using these values, the required TP Load Reduction will be calculated based upon the reduction requirement to decrease TP loads by 20%, or meet the target TP load of .28 pounds / acre / year, whichever is less stringent.

TP Load:
L = P x P_j x [Tv(S)/Rd] x C x 2.72

Where:
L = pre- or post-development pollutant load for site (pounds / year of total phosphorus)

P = average annual rainfall depth (inches) = 43 inches for Virginia
Pj = fraction of rainfall events that produce runoff = 0.9
Tv(S) = pre- or post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1" for water quality storm)
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.28 mg/L for total phosphorus
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Required TP Load Reduction:

$L_{reduction} = L_{post} - 0.8 \times L_{pre}$ OR Lreduction = L_{post} – Ptarget x SA
(whichever value is less)

Where:

$L_{reduction}$ = required TP Load Reduction (pounds / year of total phosphorous
L_{post} = post-development pollutant load for site (pounds /year of total phosphorous)
L_{pre} = pre-development pollutant load for site (pounds / year of total phosphorus)
P_{target} = Target phosphorous load (pounds / acre / year)
SA = total site area (acres)

12.5 Energy Balance for Channel Protection

The Virginia Stormwater Management Regulations now address prevention of stream channel erosion with new criteria superseding those of Minimum Standard 19 of the Virginia Erosion and Sediment Control Regulations (4 VAC 50-30-40.19), which was the previous standard. This criteria requires that *"Properties, state waters, and stormwater conveyances within or downstream of a land disturbing activity shall be protected from sediment deposition, erosion and flood damage due to unmanaged quantity of stormwater and changes in runoff characteristics. . . ."* (4 VAC 50-60-66). The term *runoff characteristics* is defined in the regulations as follows: *"Runoff characteristics include, but are not limited to velocity, peak flow rate, volume, time of concentration, and flow duration, and their influence on channel morphology including sinuosity, channel cross-sectional area, and channel slope."*

For channel protection sizing purposes, Virginia has now adopted the most widely recommended channel protection criteria of the last few years – that is, to provide 24 hours of extended detention for the runoff generated from the post-development 1-year 24-hour design storm. This runoff volume is stored and gradually released at a rate that prevents critical erosive velocities from occurring in downstream channels over the entire storm hydrograph. In addition, *man made channels* are analyzed for adequacy to convey the 10-year peak discharge within the channel banks and the 2-year peak discharge at a non-erosive velocity. These criteria, used in Maryland, New York, Vermont, Georgia, and other states result in significantly lowered discharge rates and velocities considered to be non-erosive, despite the longer impact time and increased frequency. It is relatively easy to compute at most development sites using hydrologic models. It is important to note that the control volume calculated for channel protection purposes *includes* the control volume calculated for water quality protection purposes.

Virginia has modified the channel protection sizing criteria in order to compensate for the increase in runoff volume as well. By addressing peak discharge and volume together, DCR presumes the velocity will be adequately managed as well.

To accomplish this, the regulations incorporate two versions of a method set out in § 10.1-603.4.7.(iii) of the Stormwater Management Law, as reflected in an equation developed by Fairfax County. Using this equation, the post-development peak flow rates of runoff from 1-year 24-hour storm at the development site are reduced to below the respective peak rates of runoff for the site based on (1) the pre-development land cover, if discharging to a natural stream channel that is in stable condition, or (2) good forested condition (e.g., for NRCS method, a cover type of "woods" and a hydrologic condition of "good"), if discharging to a natural stream channel that already has excessive erosion. Both of these formulas take runoff volume into account. These reductions result in a proportional improvement and are computed as follows:

(1) Where the outfall discharges to a natural stream channel that is in stable condition:

$Q_{Developed} * RV_{Developed} \leq Q_{Pre\text{-}Developed} * RV_{Pre\text{-}Developed}$, where

$Q_{Developed}$ = The allowable peak flow rate of runoff from the developed site

$Q_{Pre\text{-}Developed}$ = The peak flow rate of runoff from the site in the pre-developed condition

$RV_{Pre\text{-}Developed}$ = The volume of runoff from the site in the pre-developed condition

$RV_{Developed}$ = The volume of runoff from the site in the developed site

(2) Where the outfall discharges to a natural stream channel that already has excessive erosion:

$Q_{Developed} * RV_{Developed} \leq Q_{Forested} * RV_{Forested}$, where

$Q_{Developed}$ = The allowable peak flow rate from the developed site

$Q_{Forested}$ = The peak flow rate from the site in a forested condition

$RV_{Forested}$ = The volume of rainfall runoff expected from the site in a forested condition

$RV_{Developed}$ = The volume of rainfall runoff expected from the developed site

This method results in post-development discharges that are low enough to avoid causing channel erosion. Furthermore, the latter equation satisfies a requirement in the Stormwater Management Act (§ 10.1-603.4.7) to ". . . *improve upon the contributing share of the existing predevelopment runoff characteristics and site hydrology if stream channel erosion or localized flooding is an existing predevelopment condition*." The regulations also provide alternate methods of compliance, including using another methodology that achieves equivalent results, providing receiving channel improvements that demonstrate accommodation of post-development flows, and several exemptions from the criteria.

12.6 Example Site: Little Creek Commercial Project

This project involves the construction of a one-story branch bank building; associated traffic entrances, drive through and teller lanes, and surface parking areas. The project has sufficient land disturbing area to trigger Virginia stormwater management requirements. This project was actually constructed subject to the stormwater management regulations in existence prior to 2010.

Site Characteristics

This project is located in an inland urbanized community in the Piedmont province of Virginia. The site is not within a locally designated Chesapeake Bay Preservation Area (neither RPA nor RMA). An intermittent stream traverses through the site. There is no existing vegetation on the site. The site slopes approximately 3% towards south corner of the site (adjacent to the intermittent stream). The site is bordered on the north by an existing road.

The total site area is 2.16 acres, with 1.01 acres being disturbed and 1.15 acres of proposed impervious cover (53 % I). The soils (Edom Silty Clay Loam), which are uniform throughout the site, are in Hydrologic Soil Group C. The depth to groundwater is unknown but assumed to be deep enough to avoid creating problems. The gross building floor area is 5,000 square feet, and a minimum of 32 parking spaces are required by municipal code, based on the commercial area. The original site plan included the BMPs noted in **Table 12.3**.

Table 12.3. BMPs Specified for the Corner Commercial Project

BMP Type	Dry Detention
Area Treated by BMP (acres)	1.15
Surface Area of BMP (acres)	0.11
Storage Volume (acre-feet)	0.43
Maximum Average Depth (feet)	4
For Quality, Quantity, or Both	Quantity

Design Solution

A Runoff Reduction Method Spreadsheet solution for this site can be found at DCR's web site at the following URL: http://www.dcr.virginia.gov/documents/swmdocexsolution.xls .